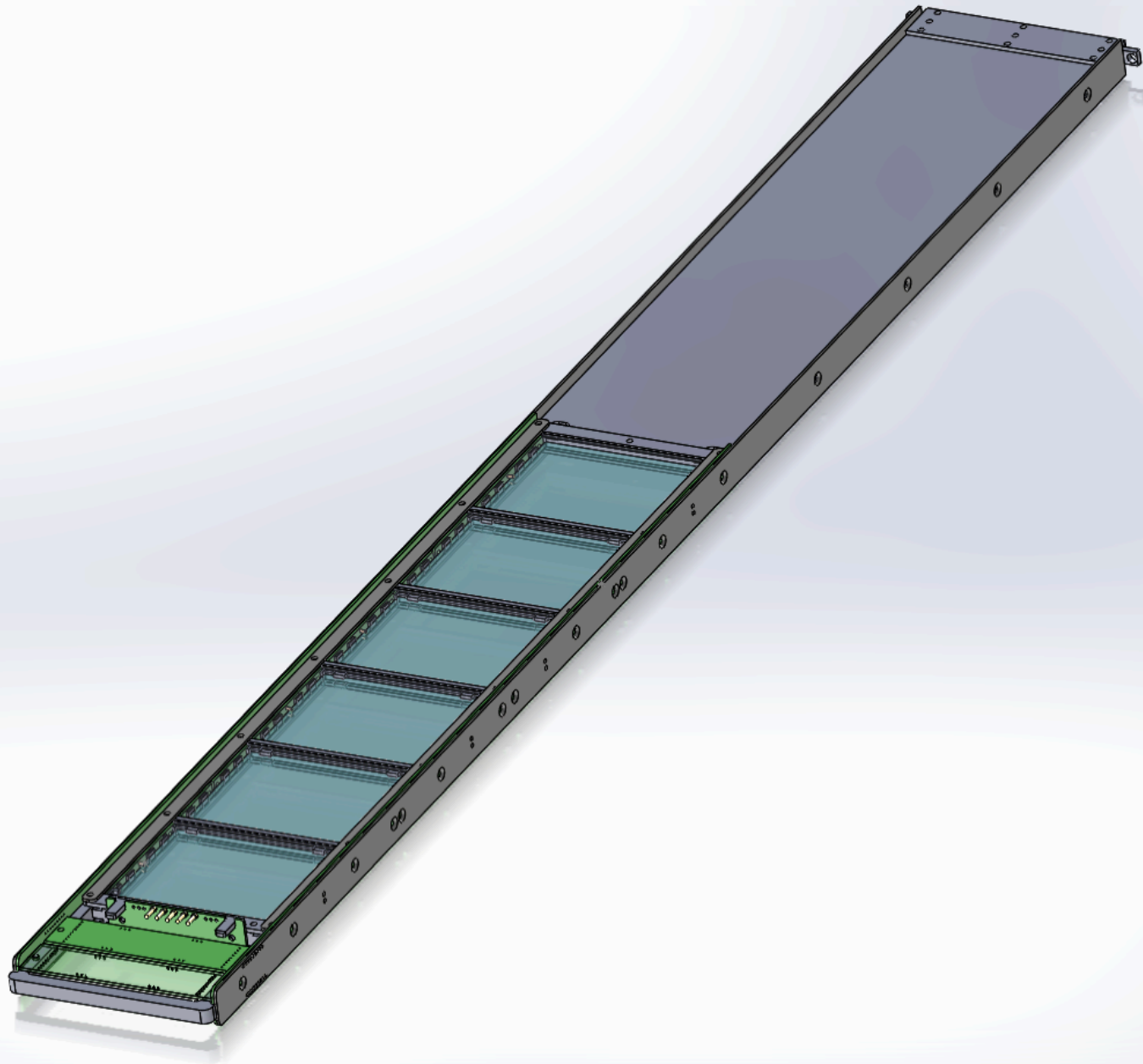
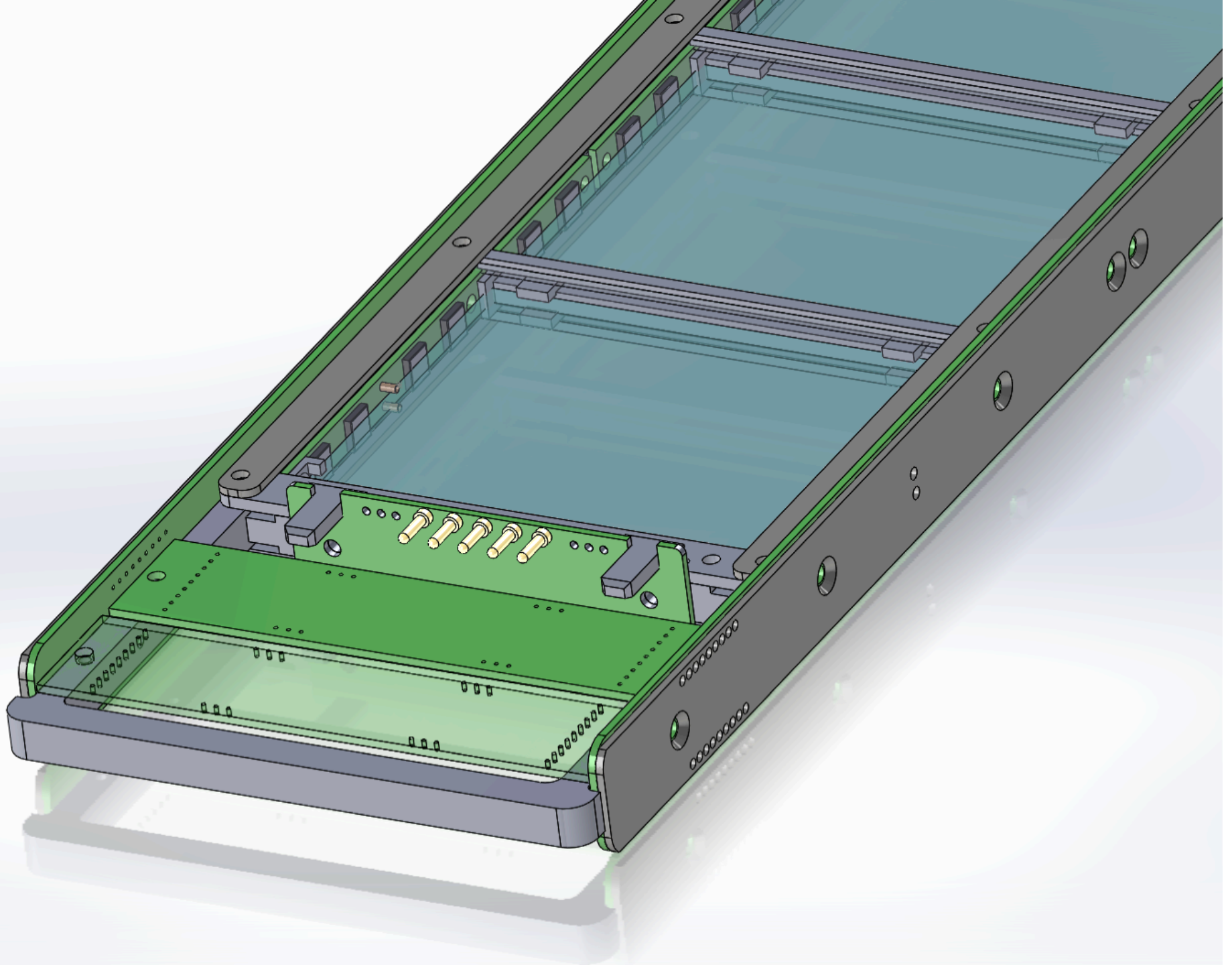


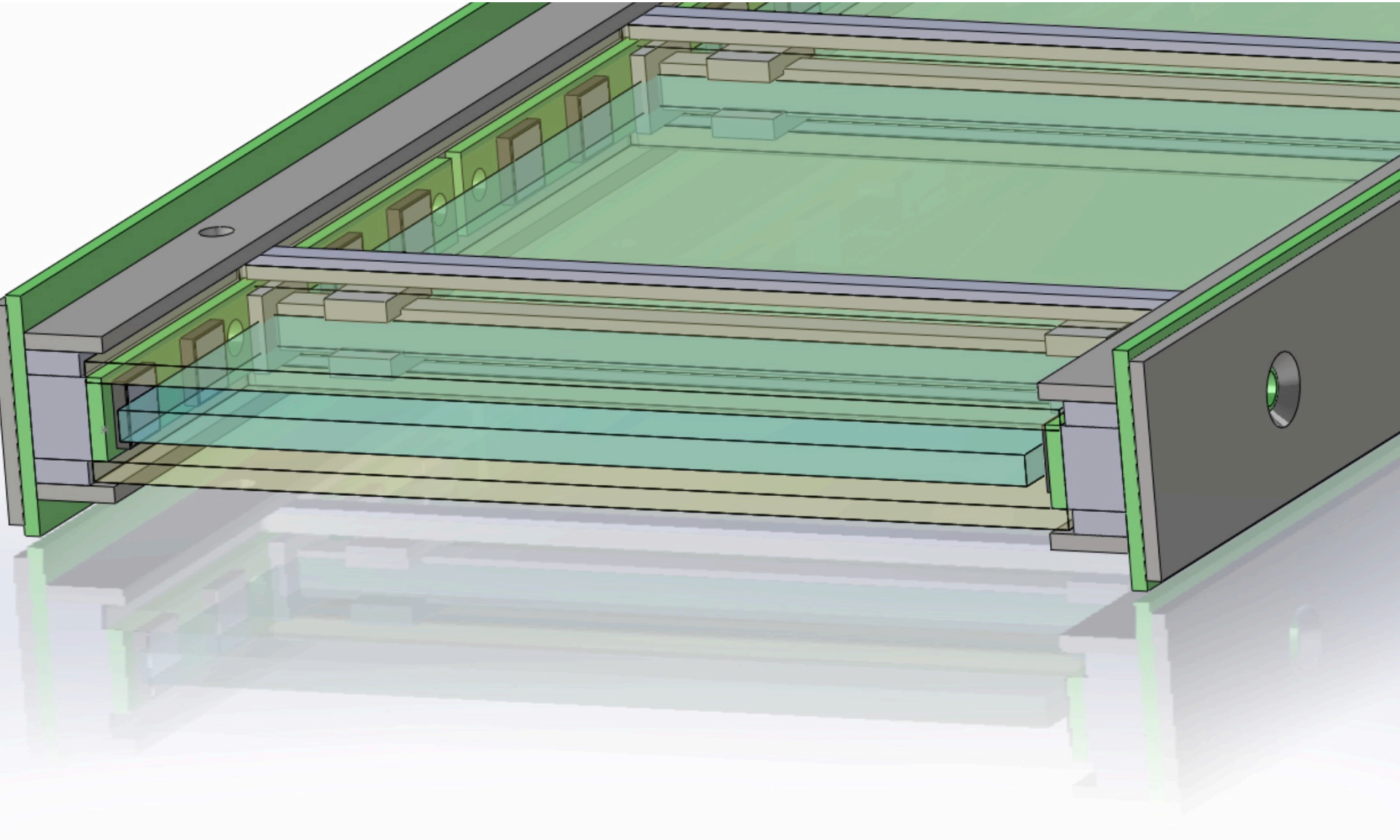
# Single-Phase Photon System Future Testing/Development Plans (And Cross-sections of PD modules)

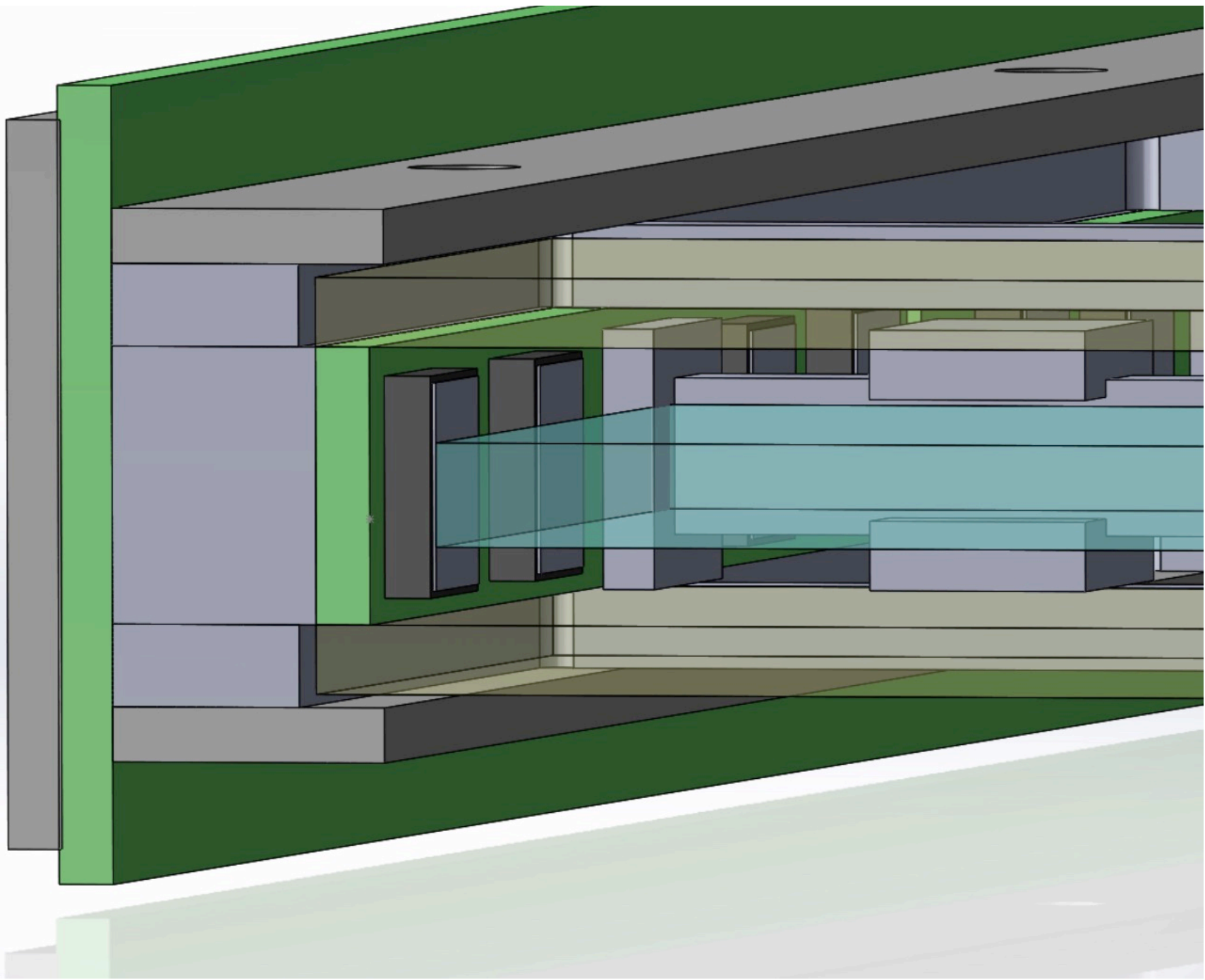
David Warner  
Technical Lead

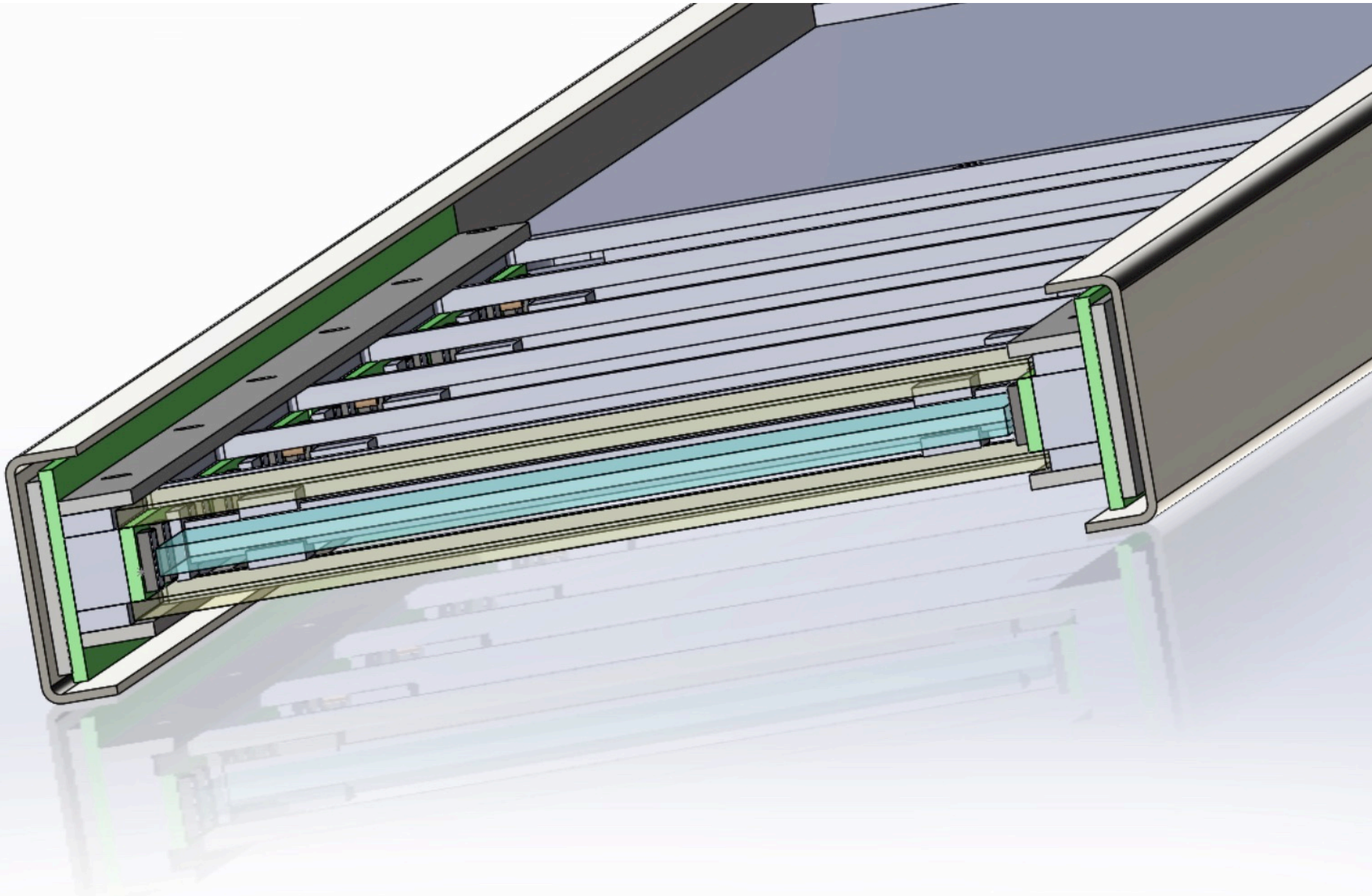
Single-Phase Photon Detector Consortium  
November 12, 2018

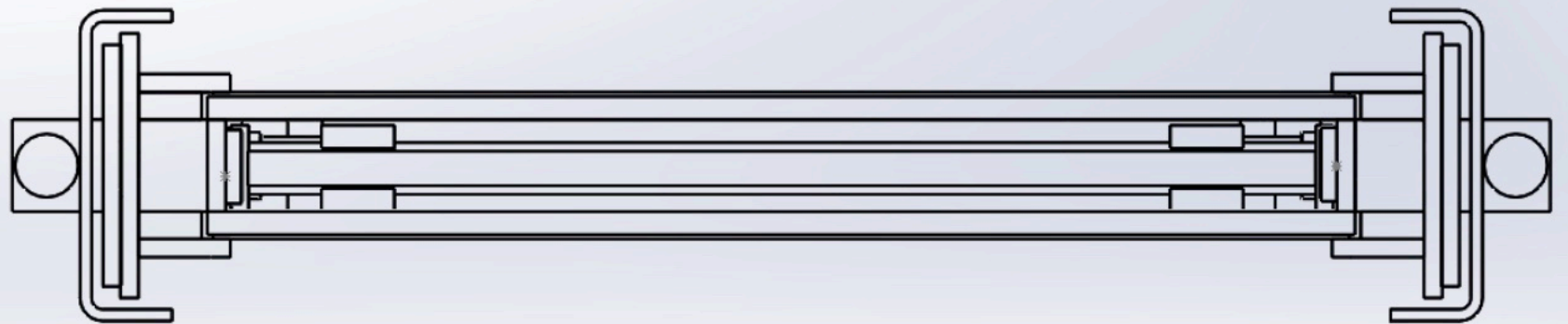


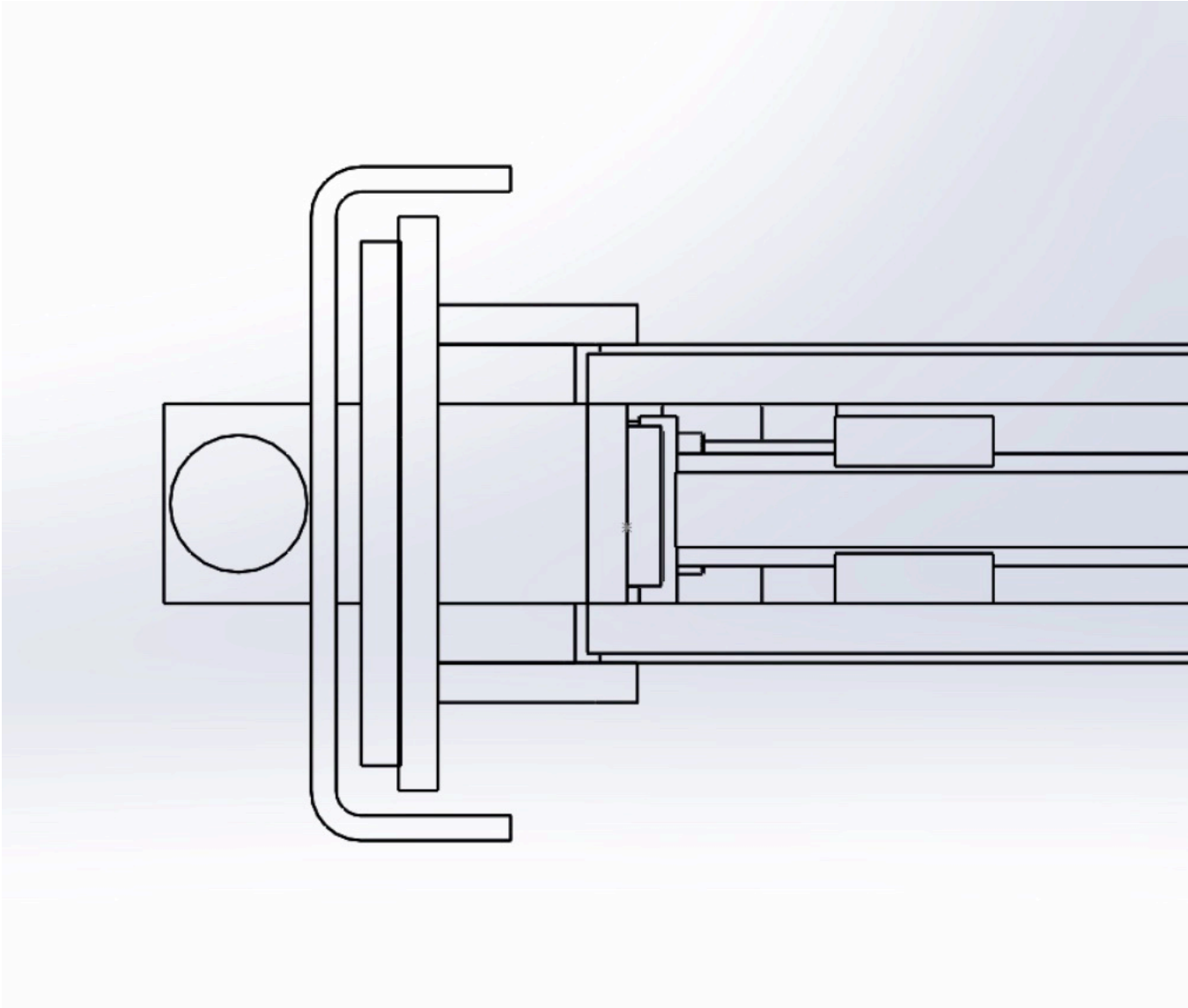




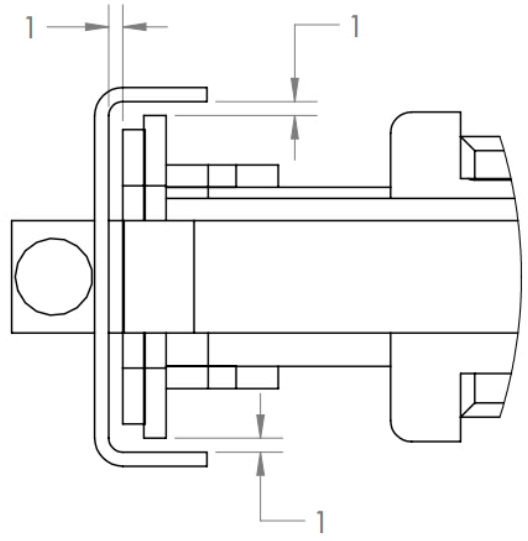
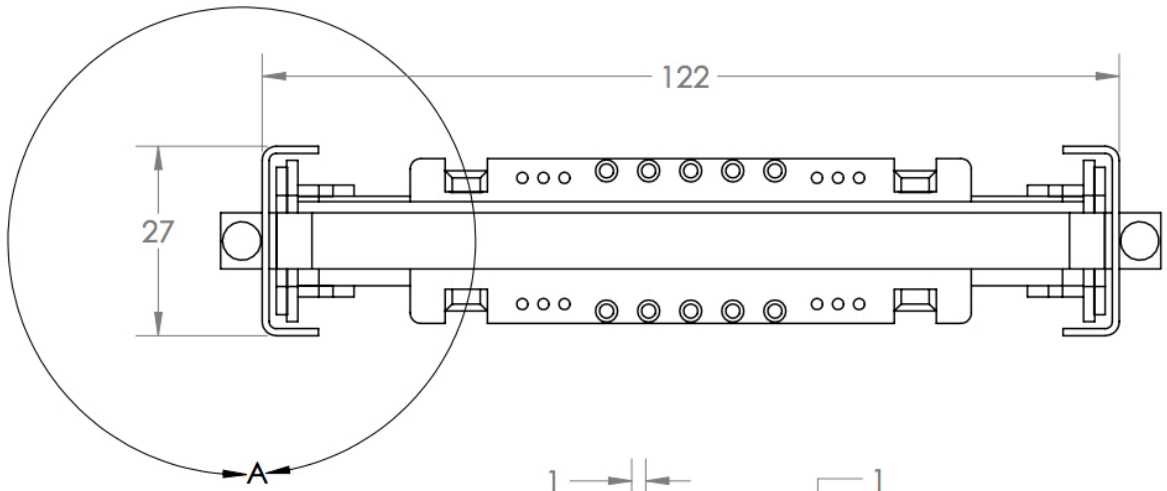












DETAIL A  
SCALE 2 : 1

Mounting Rail  
Gap Detail

# Primary Development Efforts

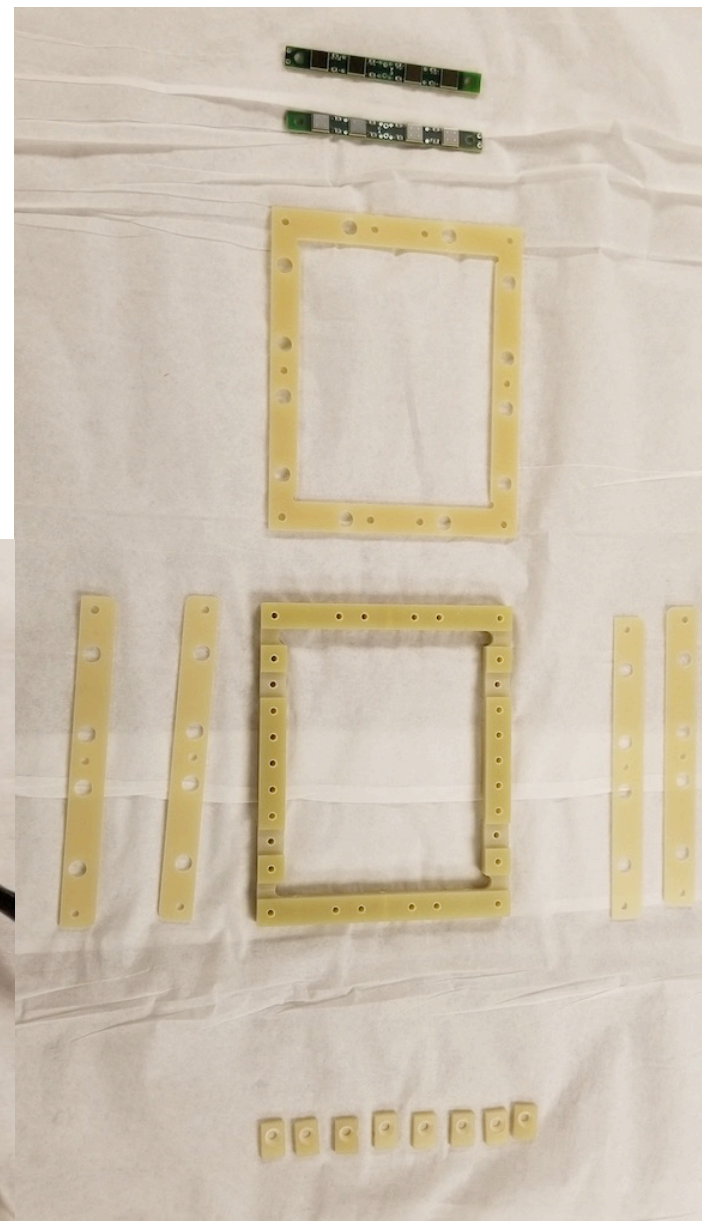
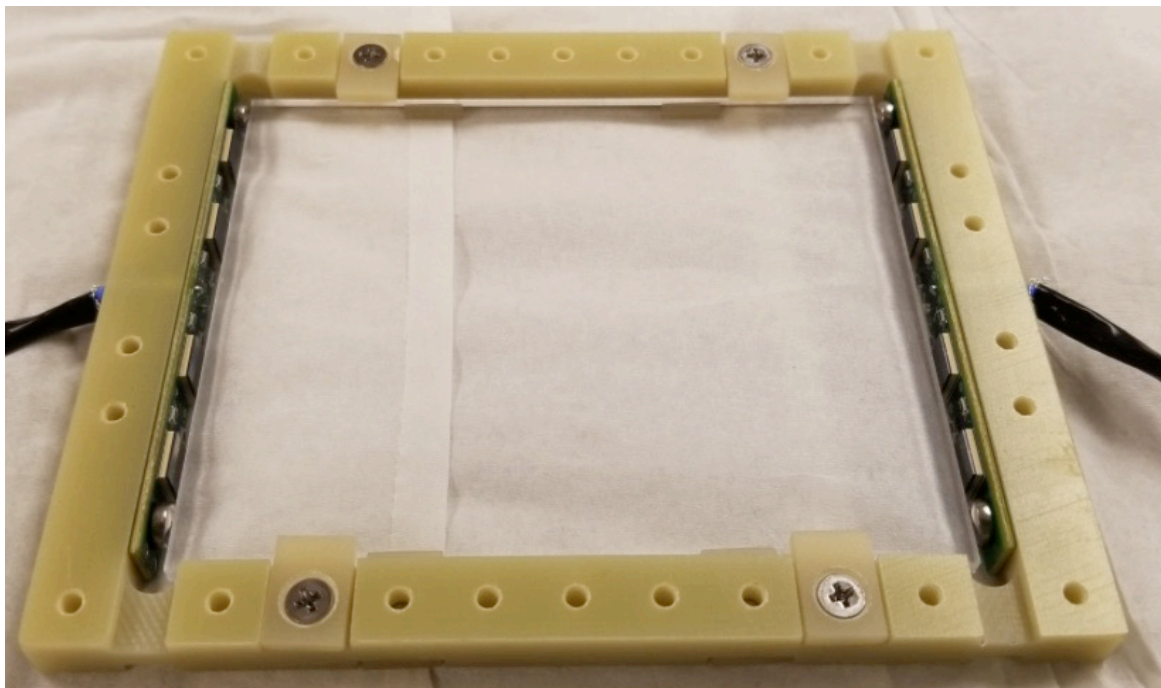
- Immediate (before TDR):
  - ProtoDUNE Analysis
  - Brazil single-cell X-ARAPUCA (X-ARAPUCA)
  - Iceberg-- Run 1, 2
- Medium-term (Before CD-2)
  - Vacuum Monochromometer X-A testing (Brazil)
  - ICEBERG-- Run 3, ...
  - PD/APA/CE interface testing (Ash River)
  - Cable/connector testing (CSU)
  - Radiological/environmental testing (SDSM)
  - WLS coating performance/stress testing (Syracuse, Brazil)
- Long-term (Before pre-production reviews)
  - ProtoDUNE II
  - Additional testing at ICEBERG

# ProtoDUNE Run 1 (See Cavanna talk)

- 2 single-sided ARAPUCA modules operating successfully in ProtoDUNE
- Expect short-term results on:
  - Relative performance of PD bar technologies
  - Absolute detection efficiency (with cosmics)
  - Long-term stability (coatings, photosensors, etc.)
  - Validation of monitoring system
  - Validation of fundamental design
- Schedule:
  - Initial short-term results expected by TDR (April 2019)
  - Additional studies continuing through CD-2 (Fall 2019) and beyond
- Resources: A new working group has been established within the SP-PD consortium to direct the ProtoDUNE analysis efforts. We expect extensive contributions from faculty, post-docs, grad students, and students consortium-wide.

# Single-Cell X-ARAPUCA

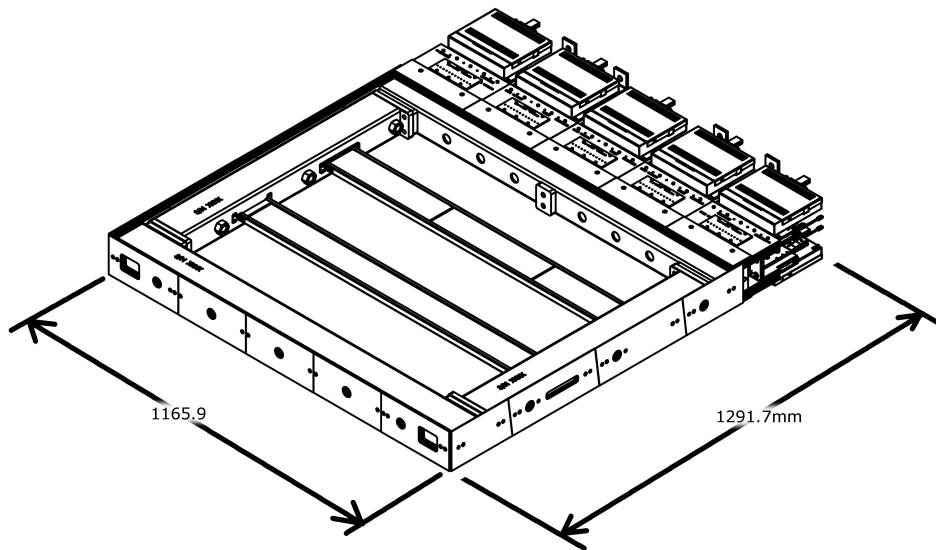
- First tests of X-ARAPUCA cell in LAr planned for week of 11/19 in Brazil
- 100 X 78mm double-sided cell
- Test cryostat and readout electronics exist in Brazil
- Faculty and students will conduct tests



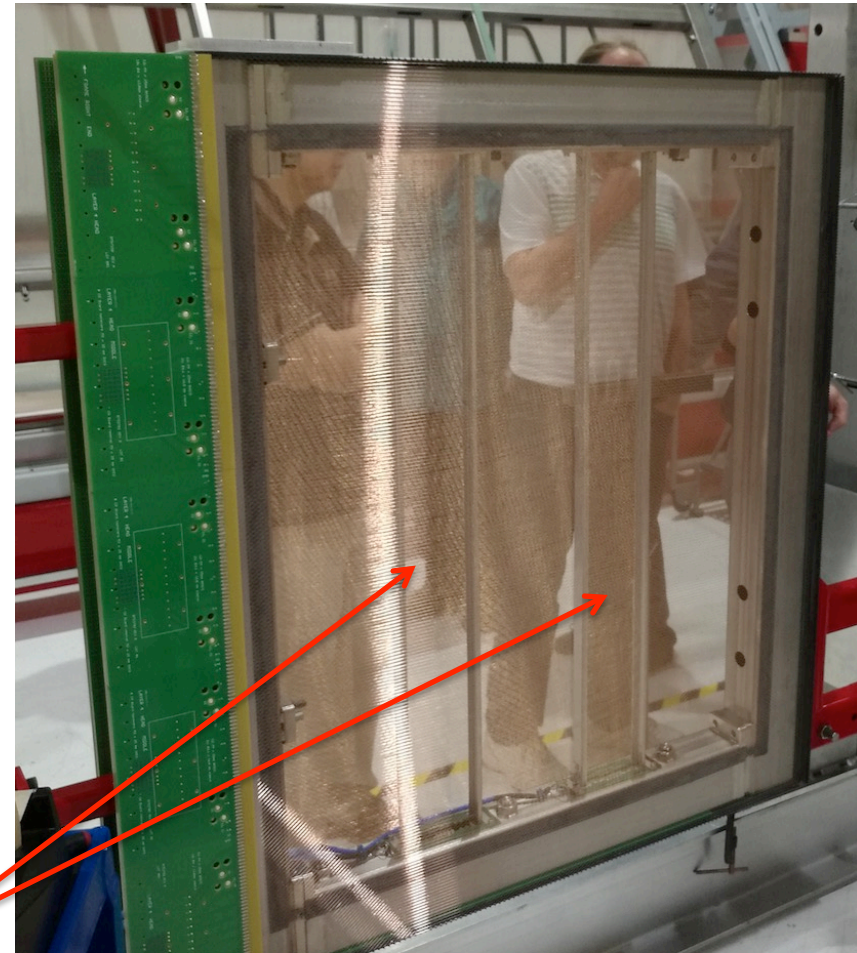
# SP-PD ICEBERG Tests

- Primary goals of testing:
  - Tests of single-sided ARAPUCA and single-sided X-ARAPUCA with TPC track information-- Similar to ProtoDUNE
  - Comparison of SSP and mu2e electronics
    - Mu2e DAQ interface available for second run (Winter 2019)
  - Interference testing between CE and PD electronics
  - Comparison of active ganging circuit prototypes
    - Available in second test run
  - DAQ/TPC interface
  - DUNE FD PD cabling scheme

# ICEBERG APA Frame

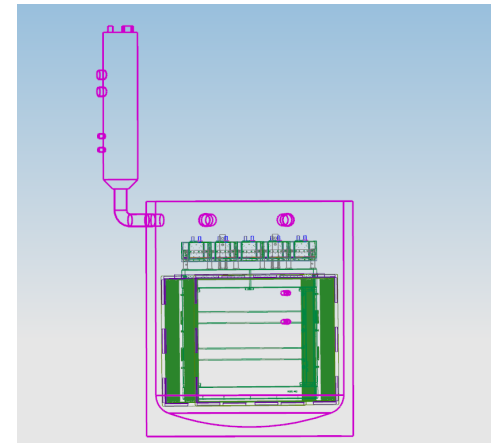
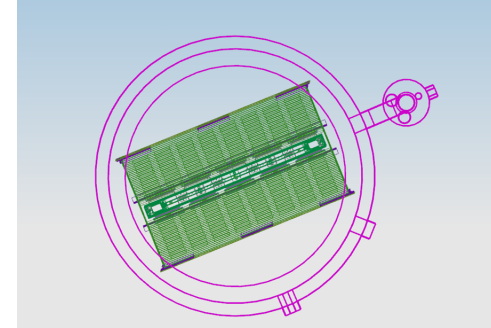
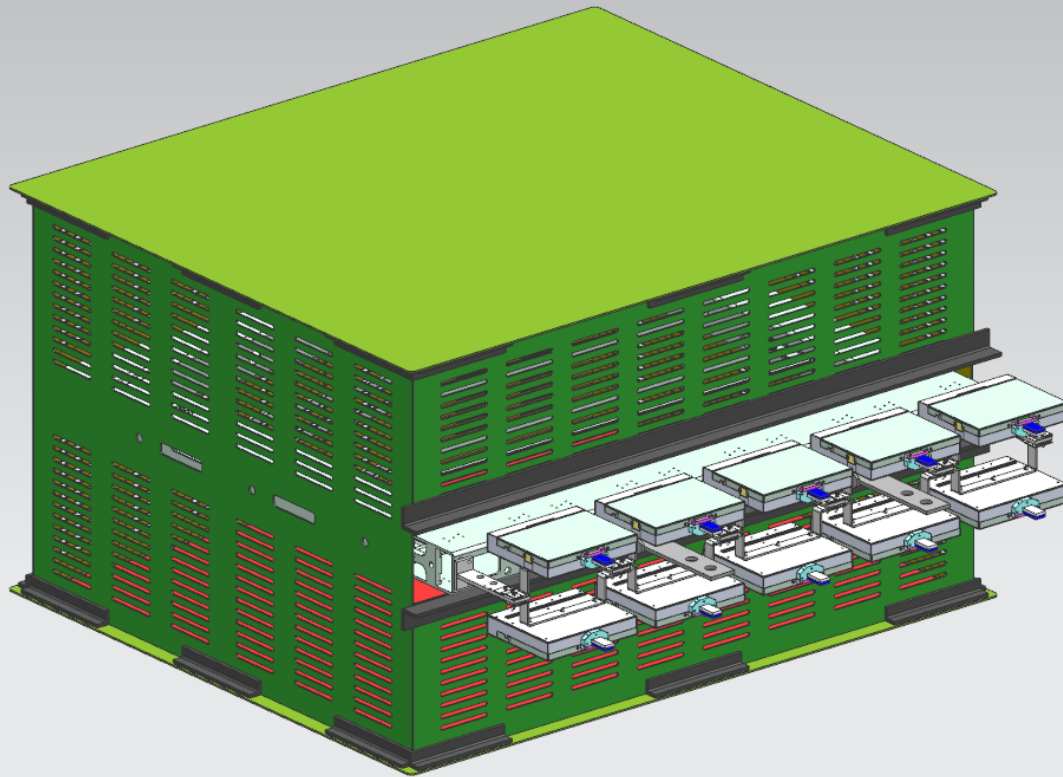


Note: Dimension is to the edge of the CE box. Cables or strain reliefs extending past the CE box take additional space.



PD rails

# Full ICEBERG TPC



# Schedule (as of November 12)

No	Major Milestones	Date
1	DAQ system Ready at PAB	8/31/18
2	APA Delivered to Fermilab	9/17/18
3	128 Channel of FEMB/WIB readout with DAQ with FEMB cold in CTS	9/17/18
4	1280 Channels of Full Electronics received from BNL	9/17/18
5	TPC Build at Fermilab	10/1/18
6	1280 Channels of CE and WIB Electronics tested at Fermilab without TPC but its cables in Cryogenic Test Stand with DAQ	10/1/18
7	1280 Channels of CE Electronics Installed on TPC	10/12/18
8	1280 Channels CE and WIB tested on TPC (Warm) with DAQ	10/26/18
9	Cryostat Ready for TPC	11/9/18
10	TPC Moved in cryostat	11/12/18
11	Test of TPC in cryostat with CE warm	11/16/18
12	Start of cooldown of Cryostat with TPC	11/19/18
13	Test of ProtoDUNE CE with TPC in Lar	12/14/18
14	Test of New CE with TPC in Lar	3/15/19

PDs needed for installation ~ 11/26/18

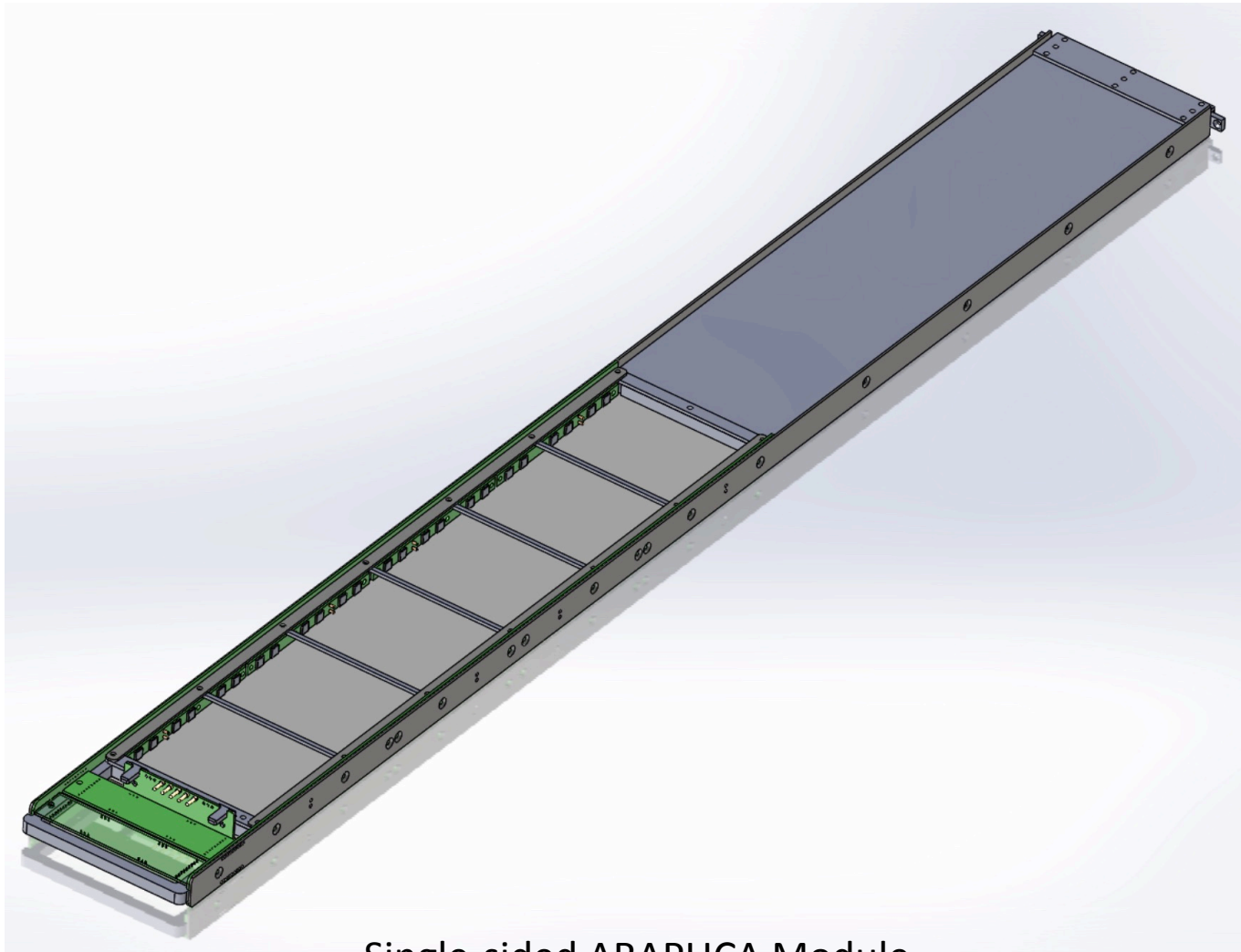
Initial Cool-down begins (11/29/18)

First Test Run ~ 12/14 – 12/24(?)

Second Test Run ~ March 2019



# PD Mechanical



Single-sided ARAPUCA Module

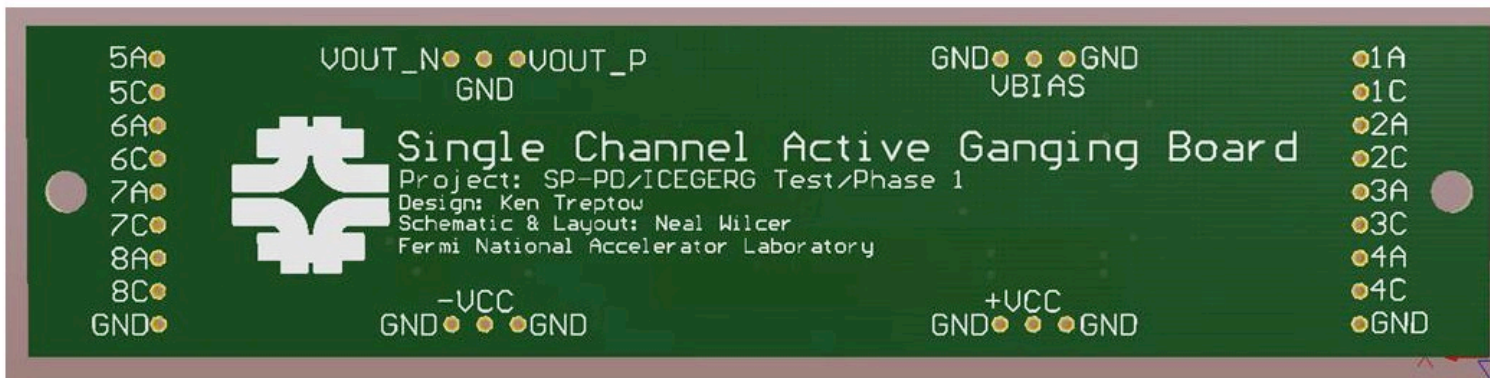
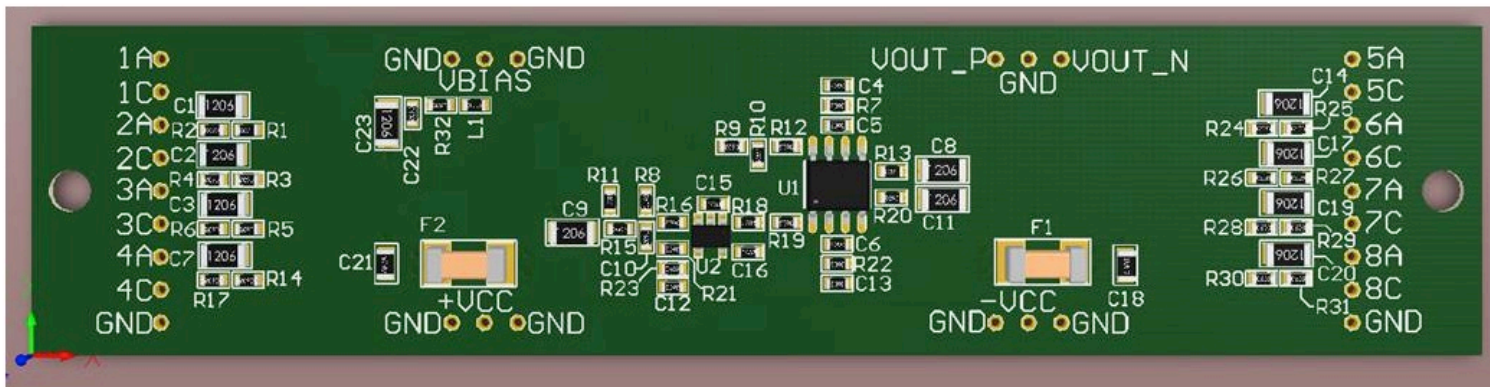
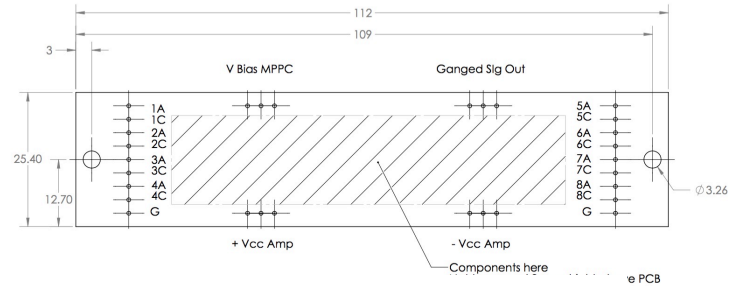
# Current Module Status

- Frame components fabricated and tested (ARAPUCA and X-ARAPUCA)
- Scheduled to arrive FNAL 11/13
- Filter plates/Vikuiti being coated at FNAL-- ready 11/14(?)
- Assembly 11/13-14
- Installation no later than 11/26



# PD Design Status

## Active Ganging PCB



From Neal Wilcer/Gustavo Cancelo

# PD Module Plans

- For Test 1 (December 2018)
  - Two supercells (one in each slot)
  - One Single-Sided X-ARAPUCA
  - One Single-Sided ARAPUCA
  - FNAL Active Ganging
  - SSP/mu2e stand alone comparisons
    - Mu2e not fully integrated into DAQ
- For Test 2 (March 2018)
  - Four supercells (two in each slot)
    - Two ARAPUCA, two X-ARAPUCA
  - FNAL and Latin American Active Ganging
  - Fully-integrated SSP and mu2e readout through DAQ

# Readout Electronics

- Primary readout in test 1 will require an SSP modified for MPPCs (50V) and ideally for RJ-45 connectors)
  - Funding secured to upgrade existing 35T SSP to ProtoDUNE standard
- Secondary readout will be provided by the mu2e electronics system.
  - System is making good progress-- still on track for December use.
- Working to understand data analysis/DAQ integration plan.

# ICEBERG Resources

- Mechanical
  - Design and fabrication CSU
  - Assembly and installation CSU, FNAL
- Optical coatings
  - Funded by US Project and LDRD, at FNAL
- Electronics
  - MPPCs mounted and tested at CSU
  - Active ganging fabricated at FNAL (Run 1) and FNAL and Paraguay (Run 2)
  - SSP Modifications at ANL
  - Mu2e modifications at UM, FNAL
- Operations, Analysis
  - ICEBERG operations group formed, led by Carlos Escobar
  - Analysis at many consortium institutions

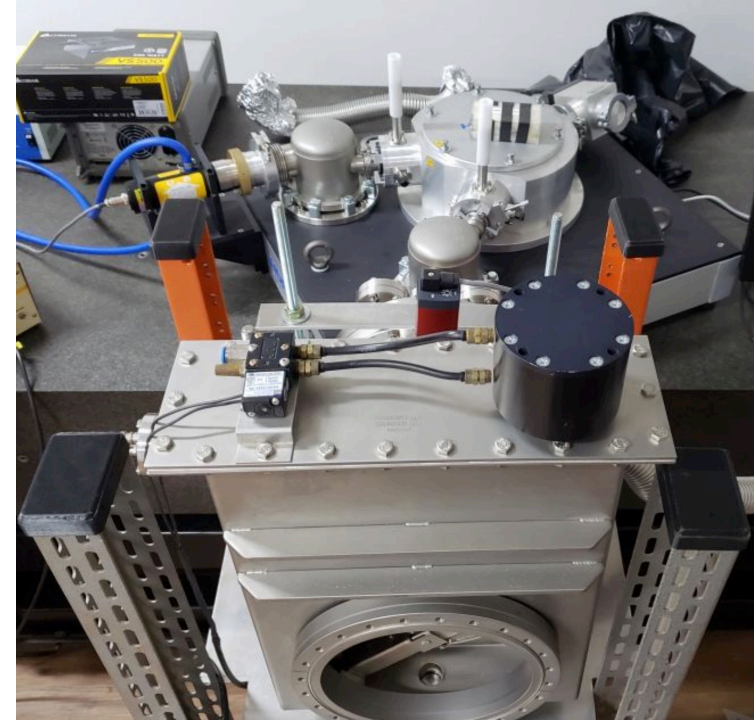
# WLS Coating (Syracuse)

- WLS performance studies of different coating/substrate combinations
  - VUV measurements in scanning X-Y scanning chamber (shown)
  - 430nm light transmission measurements through filters/coatings (reflector foil studies)
- Testing thermally-stressed (rotated in LAr bath) coated substrates in X-Y scanner before and after stressing.
- Required facilities/resources
  - VUV Monochromator, test stands, Visible light transmission measuring equipment on hand
  - LAr test stand commissioning in January
  - Tests run by faculty (Whittington), grad student



# VUV Monochromator Coatings, Detector Tests

- Component and prototype testing is underway in Brazil, focusing on
  - Coating filters and reflectors using in-house vacuum deposition
  - Testing of coated samples in VUV monochromator
  - Testing of ARAPUCA and X-ARAPUCA prototypes in monochromator

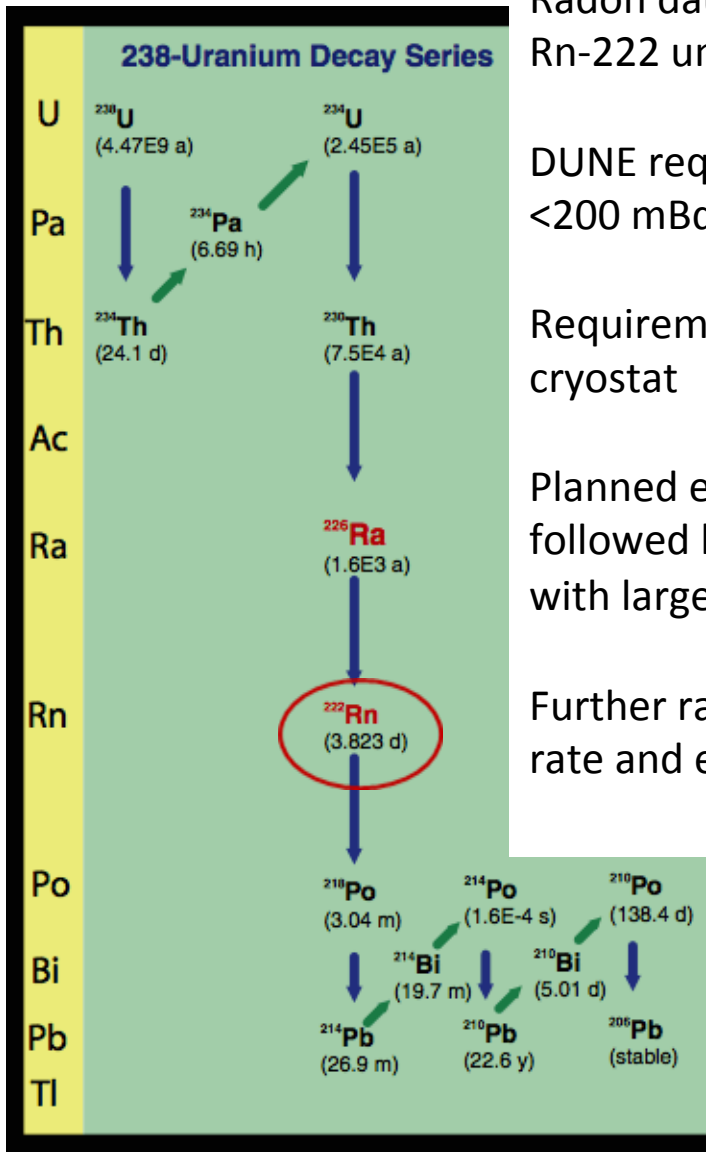




# Materials/Environmental testing

- Materials testing will continue at SDSM
- Important studies will include
  - Effects of elevated temperature on PD WLS coatings
  - Humidity effects
  - Lighting requirements, both long and short term, to validate pre-35T measurements
- Resources required:
  - Environmental exposure stand (controls humidity and temperature)
  - Light exposure chamber (aging studies for coatings)
- Schedule: Ongoing now. Additional early results by TDR (May 2019). Long-term testing will continue through pre-production reviews (and beyond).

# Radiopurity Studies



Radon daughter plate-out expected from high levels of Rn-222 underground (200 – 300 Bq/m<sup>3</sup>)

DUNE requirement on ANY surface alpha-activity on PDs in FD: <200 mBq / m<sup>2</sup> (to be subdominant to Ar-39 next to PDs)

Requirement is expected to be exceeded for PDs installed early on in cryostat

Planned exposure tests in 2018/2019 of PDs underground at SURF followed by radiological screening for plated-out alpha-activity on PDs with large AlphaBACH detector at SDSMT

Further radiological simulations are planned to study impact on FD PD rate and energy threshold

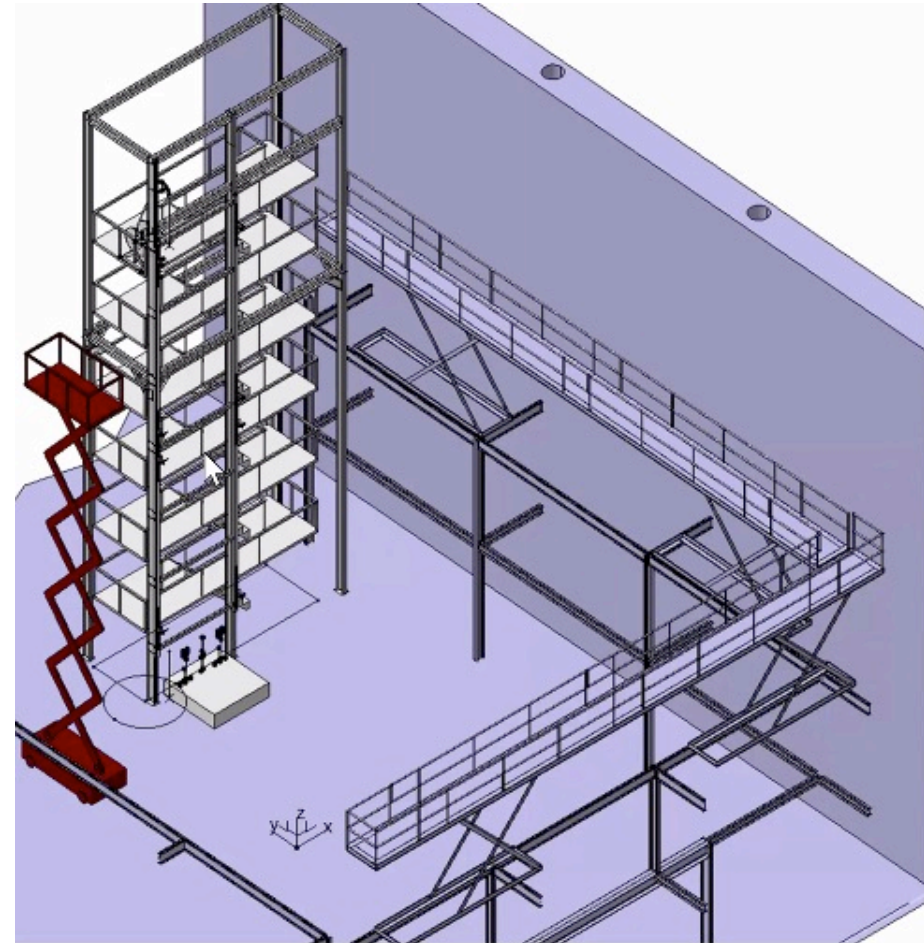
=> Need to additionally protect PDs during manufacturing, shipping, testing and installation to minimize radon daughter plate-out

# Radiopurity Resources

- SDSM (Reichenbacher) is making a major contribution of his time and resources to this effort:
  - Labor: 1 Faculty (Reichenbacher), 1 grad student, 1 student
  - Low-level radiation monitoring equipment to monitor Radium decay daughters and dust contamination of PD surfaces
- Schedule
  - Initial measurements underground (4850) for dust/radium deposition on test surfaces in Dec. 2018 for 2 months
  - Measure Po “Growing in” in March 2019 and re-measure in August 2019
  - Grad student will run radiological simulations in August 2019 to determine the criticality of plated-out alpha activity.
  - Continue monitoring through detector installation

# APA-PD-CE Interface Ash River

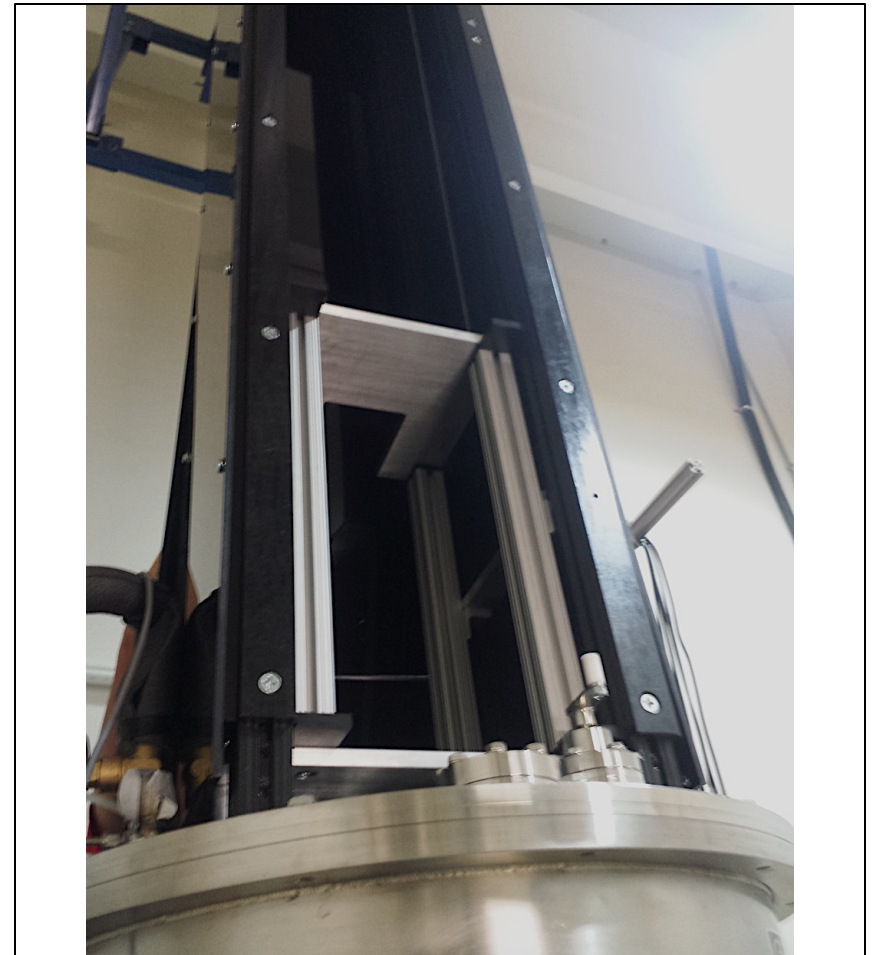
- Full-scale testing of APA-PD-CE integration/installation will occur at Ash River
- Will allow testing of
  - Connection of upper and lower APA frames with PD cables
  - Practice of PD installation
  - Testing of full length PD cable suite
- Required resources
  - Sample cables
  - Cable connector plates
  - Mounting plates for connectors joining upper lower APAs
  - Mechanical PD model (no active components)
  - Will be assembled at CSU. CSU will lead integration testing
- Planned for Spring, 2019



**APA Assembly Area at Ash River**

# Cabling, Full-Scale Module Testing

- Full scale (Up to 2.5m) modules can be tested in the CDDF Cryostat at CSU
- Allows for testing of
  - Internal cable connectors
  - Full-scale module contraction effects
  - Full-scale cryogenic performance qualification
- Capable of operation with LAr for PD module design qualification
- Resources:
  - Test stand (CDDF) exists at CSU
  - Labor (test bed assembly, testing, analysis) provided by CSU students, grad students, technical staff.



# ProtoDUNE Second Run

- A potential second ProtoDUNE run offers several opportunities to the PD consortium
  - Tests of multiple full-size PD modules inside a TPC to confirm the final design
  - Opportunities to test PD performance enhancers
    - CPA reflector foils
    - Xenon doping
- Significant resources would be required for such a run, and would need to be identified
  - Financial
  - Labor/Engineering/ Scientist

# Summary

- Additional development of the X-ARAPUCA/PD system design is planned for the short, Medium and long term.
- All major areas of uncertainty will be covered by these plans
  - Mechanical design/component selection
  - Interfaces
  - Electronics/readout
  - Performance
- Our development plan will leave us with a 60% design by the time of the TDR, and ready for CD-r in late FY2019